“A Complete and Unbiased View of Ultra-massive Galaxies at 3<z<4”

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Distant UMGs to Constrain Theoretical Models

(Steinhardt+2016)
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(Hirschmann+2016 - GAEA SAM)

(Pillepich+2018 - TNG300)
Distant UMGs to Constrain Theoretical Models

NEED OF A LARGE COMPLETE AND UNBIASED SAMPLE OF UMGs at z=3-4
Deep Multi-wavelength Data Over Wide Area

- Deep ZYJHKs from VIDEO (DR2) over ~12 deg² (Jarvis +2013) - \textbf{Ks}(90\% completeness)<23.0-23.5 AB
- Deep optical (u-to-z) imaging from HSC-SSP (Hayashi +2018), DES (Abbott+2018), CFHTLS (Hildebrandt+2009; Gwyn+2012), VOICE (Vaccari+2016)
- Deep IRAC (at least CH1/2) from SERVS (Mauduit +2012) and DEEPDRILL (Lacy+2014)

- SEDs sampled by 28 photometric bands from the u-band to the IRAC 8 micron band.

- Ancillary data in X-ray, infrared Herschel, and radio for complete AGN identification.
Ultra-Massive Galaxies at 3<z<4

\[ \log \left( \frac{M_{\text{star}}}{M_{\odot}} \right) \]

XMM

UMGs

CDFS

(Annunziatella, DM, et al.)
Ultra-Massive Galaxies at 3<z<4

176 UMGs at 3<z<4 with log(M_{star}/M_{Sun})>11.2 [70 with log(M_{star}/M_{Sun})>11.5] in XMM+CDFS (~6.5 deg², effective), with photometric redshift accuracy of 3-4%.

[*Chabrier IMF adopted]

(Annunziatella, DM, et al.)
Examples of SEDs of UMGs at 3<z<4

Quiescent

Unobscured star-forming

Dusty star-forming

(Annunziatella, DM, et al.)
Diversity in UMGs at 3<z<4

(Annunziatella, DM, et al.)

- 25% UVJ-selected quiescent galaxies
- 60% UVJ-selected dusty star-forming galaxies

UVISTA DR1 - 1<z<3
3<z<4 UMGs

\[ \tau = 100, A_v = 0.2 \]
\[ \tau = 100\text{Myr} \]

CSF, \( A_v = 2 \)

\( A_v = 1 \text{ mag} \)
Diversity in UMGs at $3<z<4$

(Annunziatella, DM, et al.)

- 25% UVJ-selected quiescent galaxies
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UVISTA DR1 – $1<z<3$

$3<z<4$ UMGs

- $\tau=100$, $A_v=0.2$
- $\tau=100\text{Myr}$

CSF, $A_v=2$

$A_v=1$ mag

(DUSTY SFing)

UVJ selection from Straatman+2016

(Martis, DM, et al. 2016)

2.5<$z<$3

Fraction

$log (M_{\text{star}}/M_\odot)$
Main Sequence and Quiescent UMGs at 3<z<4

(Annunziatella, DM, et al.)

XMM-2599
SMF of Quiescent UMGs at 3<z<4

This study - quiescent

Muzzin+2013 - quiescent

(Annunziatella, DM, et al.)
The majority of UMGs is found in regions with intermediate-to-high densities.

(Annunziatella, DM, et al.)
XMM-2599: most massive quiescent galaxy at 3<z<4 spectroscopically confirmed

Photometric properties:

\( m_K = 21 \) AB
\( z_{\text{phot}} = 3.4 \)
\( \log(M_{\text{star}}/M_{\odot}) = 11.46 \)
SFR < 0.06 \( M_{\odot}/\text{yr} \)
\( A_V = 0.1 \) mag

(Forrest, Annunziatella, DM, et al., 2019)
**Spectroscopic properties:**

\[
\begin{align*}
    z_{\text{spec}} &= 3.493^{+0.003}_{-0.008} \\
    \log(M_{\star}/M_{\odot}) &= 11.49^{+0.02}_{-0.03} \\
    \text{SFR (} M_{\odot}/\text{yr} \rangle &= 0.03 \\
    A_V &= 0.05^{+0.15}_{-0.05} \text{ mag}
\end{align*}
\]

(Forrest, Annunziatella, DM, et al., 2019)
Star formation started at $z \approx 7$; half of its stellar mass built by $z \approx 5.7$, and quenched since $z \approx 4.1$.

Period of $\sim 0.5$ Gyr during which SFR $> 1000 \, M_{\odot}/yr$
XMM-2599: progenitors?

Mass evolution of XMM-2599 is consistent with massive sub-mm galaxies at 5<z<7

(Forrest, Annunziatella, DM, et al., 2019)
XMM-2599 vs model predictions

• XMM-2599: the most massive spectroscopically confirmed quiescent galaxy at $z>3$
• Models have trouble quenching these massive galaxies rapidly enough

(Forrest, Annunziatella, DM, et al., 2019)
XMM-2599 vs model predictions

XMM-2599: the most massive spectroscopically confirmed quiescent galaxy at $z>3$

Models have trouble quenching these massive galaxies rapidly enough

(Forrest, Annunziatella, DM, et al., 2019)
Discovered proto-cluster at $z=3.36$

Absorption Line UMG

Emission Line UMG

- Other ELG

$N = 69, \sigma_{\text{NMAD}} = 0.015$

$N > 5\sigma_{\text{NMAD}} = 6$
Summary

☑ Presented the largest photometric sample of ultra-massive galaxies at 3<z<4, with log(M_{star}/M_{Sun})>11.2 (176 candidates over 6.5 deg^2), providing an unbiased picture of the extreme massive population at 3<z<4.

☑ 20-25% quiescent fraction / 60-65% are dusty star-forming.

☑ Presented results on stellar mass function of quiescent galaxies, and environment of UMGs

☑ Spectroscopic confirmation of the most massive quiescent galaxy at z>3, XMM-2599: formed half of its stellar mass by z~5.7, quiescent since z~4.1,

☑ XMM-2599 provides evidence that latest generation of theoretical models are lacking a quenching mechanism that is rapid enough to produce galaxies like XMM-2599